two different directions. These antenna systems were developed over the years to allow customers to receive signals from adjacent markets or stations within the same market with disparate tower locations. Typically, these antenna systems consist of two receive antennas that are combined with a simple 3-dB hybrid combiner. This allows a receive antenna system that is directional in the bearings of the desired signals without the need for re-orienting the antenna when changing channels.

And when those solutions are unavailable to a viewer, manufacturers have long offered reasonably priced rotors that enable a rooftop antenna to be moved to achieve the best orientation for a particular station. In fact, today rotors are available with advanced features, including presets for particular stations as well as remote control operation. For example, the Channel Master Model 9521A allows the consumer to program the rotor controller to respond to the infrared (IR) commands from their TV set's remote control. The rotor controller receives these channel commands and then actuates the rotor to the appropriate bearing for the channel requested by the TV set remote control. Thus, the rotor automatically orients for the consumer without the need to operate the rotor manually. This makes the antenna orientation experience appear seamless to the viewer.

Table 3 illustrates some of the available rotor units.

Manufacturer	Model	Special Features	Cost
Pacific Custom Cable	200-600		$95.00
Pacific Custom Cable	200-603	Remote Control	$105.00
Channel Master	9521	Remote Control with 69-channel memory	$69.95
Centron	AR-500XL	Remote Control with 12-channel programmable memory	$69.95
GEMINI	OR360	Heavy Duty Automatic Antenna Rotator	$49.95
Hy-gain	AR-35		$69.95
JVI	MAR160		$54.95
Magnavox	M61415		$49.95
Radio Shack	15-1245	Separate remote controller ($54.99 extra)	$74.99
Warren Electronics	32-9015		$59.95
Antennacraft	TDP2		$94.88
Yaesu	G-450A	Handles larger weight loads then the others above	$249.00

Table 3 Antenna rotors.

45. __Antenna gains__. The Commission's DTV planning factors assume antenna gains of 4 dB for low-VHF, 6 dB for high-VHF, and 10 dB for UHF. These assumptions are realistic. As recently tested by engineer Kerry Cozad of Dielectric, for example, the measured Channel Master 4228 antenna offers gain figures for high-VHF digital signals and for UHF digital signals that exceed those specified in the planning factors (**Ref 12**). As Mr. Cozad's paper shows, the Channel Master antenna achieves gains of about 14 or 15 dB for most UHF channels, while the planning factors call for a gain of only 10 dB for UHF. For high-VHF, the paper shows that the Channel Master antenna achieves gains of about 8 or 9 dB, compared to the assumption in the planning factors of only 6 dB of gain. Even for low-VHF -- a channel range in which very few network affiliate stations will broadcast in digital -- the Channel Master antenna offers gains nearly as high as those specified in the DTV planning factors (the slight deficiency in the gain values at low-VHF can easily be overcome with an LNA). The Channel Master antenna is available from a variety of vendors for between $38 and $50. Further information can be found at www.winegard.com/products.htm.

46. Another antenna to consider is the Winegard Square Shooter SS-1000 consumer antenna. This new high-VHF and UHF antenna exhibits good gain and front-to-back characteristics despite its aesthetically-pleasing design and compact size of 16" W x 16"H x 4" D. The antenna can easily attach inconspicuously to the side of a wall, or even act as an extension to a satellite dish (*e.g.*, it meets DirecTV and Dish Network's wind load requirements). The 4.5 dB reported gain across the UHF band is below the FCC planning factor, but can be easily be increased using an external LNA. Or, the related Winegard Square Shooter 2000 can be used; it is the same antenna design, but has an *internal* broadband 12-dB amplifier that boosts the signal (equivalent net antenna system gain averaging about 15 dB across the UHF band), lowers the effective system noise figure, and minimizes any mismatch losses. The Winegard SS-1000 antenna is available from Solid Signal for $87.99 and the SS-2000 is available for $98.99. *See* www.solidsignal.com/search_results.asp?main_cat=0&search_crit=square+shooter&SiteREF=SSCOM. Further information can be found at www.channelmaster.com/home.htm.

47. __Front-to-back ratio__. The DTV planning factors assume an antenna front-to-back ratio of 10, 12, and 14 dB for low-VHF, high-VHF, and UHF, respectively. The Channel Master 4228 rooftop antenna does considerably better than the planning factors assume, with a front-to-back ratio of roughly 25 dB for VHF and 18 dB for UHF. Based on manufacturer's published specifications, the Winegard Square Shooter SS-1000 and SS-2000 antennas have 16 dB of front-to-back ratio at Channel 32 (with an average of 15 dB across UHF band).

48. __System noise figure__. The Commission's planning factors assume a receive system noise figure of 10 for VHF channels and of 7 for UHF channels. These VHF and UHF noise figure values plus the accepted 8-VSB system's 15 dB white noise threshold for errors predict minimum receiver input levels (also called sensitivity values) of –81 dBm and –84 dBm,

respectively. Although there is little published data about receiver noise figures for DTV receivers, use of a low-noise amplifier (discussed in the next section) effectively reduces the overall noise level of the system.

49. **Use of low-noise amplifier**. Consumers can readily, and at modest cost, do much *better* than the DTV planning factors for receive sites by using a mast-mounted low noise amplifier (LNA), or "preamplifier," which boosts the signal before it is sent through the downlead cable into the consumer's home. **Figure 3** contains the block diagram of receive site system that uses an LNA to provide more margin for DTV reception. The equations, similar to the ones in **Figure 1**, illustrate how the minimum antenna input field strength can be calculated. The use of a preamplifier has three advantages. First, the preamplifier increases the received signal level before being attenuated in the downlead coaxial cable. Second, the preamplifier's low noise level effectively lowers the equivalent noise figure of the receive system since the LNA is an external device that can easily have a noise figure that is 4-7 dB *lower* than the DTV tuner. Finally, the preamplifier mitigates any impedance mismatch loss between the antenna and the DTV receiver (tuner). These benefits allow an LNA to easily add at least 12-15 dB (and often significantly more) of *effective* gain to a receive system, even with a "below-par" receive system that would not otherwise meet the FCC planning factors.

50. Low-noise amplifiers are readily available at moderate expense for mounting on the rooftop antenna mast. Many work with both the VHF and UHF bands, while others are optimized for just the UHF band. Because of their benefits and low cost, preamplifiers are commonly used to boost reception at locations when signal strength may be close to the margin. Four common LNAs that are currently on the market were tested in the laboratory, and the performance test results are summarized below in **Table 5**.

Parameter	Channel Master Titan 2	Winegard AP-8700	Blonder-Tongue CMA-Uc	Radio Shack 15-2507
Average UHF Gain	23 dB	19 dB	18 dB	30.1 dB
Average UHF Noise Figure	3 dB	3.5 dB	4 dB	4.8 dB
Cost	$56.99	$78.58	$164.00	$59.99

Table 5 LNA "preamps".

51. Signal amplification is available in values between 18–30 dB and the noise figure value between 3–5 dB. The availability of these preamplifiers (and similar ones from other manufacturers) provides a substantial "cushion" against the possibility of any losses not specifically accounted for in the planning factors.

52. [Intentionally omitted.]

53. **Downlead line loss**. As the planning factors recognize, a certain degree of signal loss occurs as the signal moves from the rooftop antenna through a cable to the household's television equipment. The planning factors assume losses of 1 dB for low-VHF, 2 dB for high-VHF, and 4 dB for UHF. Based on published data for standard RG-59 and RG-6 coaxial cable, these figures are conservative. RG-6 coaxial cable, which is commonly used in satellite installations, offers other benefits as well: improved shielding to help prevent extraneous signals (such as signals generated within the home) from leaking into the system. A brief summary of different coaxial cable types is in **Table 6**. Note that the loss numbers stated below are for the worst case -- Channel 51 -- within the digital core (Channels 2-51).

Manufacturer Model #	Belden 1186A	Belden 1152A	Belden 1189A	West Penn 819	West Penn 6350	Units
Type	RG-59	RG-6	RG-6	RG-59	RG-6	-------
Impedance	75	75	75	75	75	Ohms
Attenuation (UHF CH 69)	2.9	3.3	2.7	3.1	2.3	dB/50'

Table 6 Coaxial cable types

The most expensive cable shown above costs about $25 for the typical 50' cable lengths assumed in the FCC planning factors. Thus, it is reasonable to assume that consumer setups will be at least consistent with the DTV planning factors for downlead line loss.

54. **Conclusion**. In short, consumers can acquire, at relatively modest expense, reception equipment that is substantially better than what is assumed by the DTV planning factors. In determining how to measure the availability of an over-the-air digital signal at a satellite subscriber's household, the Commission should therefore assume that, in the words of the Notice (at ¶ 6), that "households will exert similar efforts to receive DTV broadcast stations as they have always been expected to exert to receive NTSC analog TV signals," including the use of directional rooftop antennas with significant gain. For households where signal strength is close to the margin, the optional availability of a modestly-priced preamplifiers provides a significant buffer against any signal losses not accounted for in the planning factors.

Procedures For Measuring
Signal Intensity At Individual Households

55. In its Notice of Inquiry, the Commission asks whether its existing procedures for measuring signal intensity at individual households for purposes of the Satellite Home Viewer Act (and successor legislation), which are set forth in Section 73.686(d), are appropriate for measuring digital signal strength. NOI, ¶ 12-13. As the Notice explains, the existing procedure

calls for measurements to be taken at five locations near the household, with an antenna raised to nine meters above ground level.

56. The Commission's existing procedures for measuring analog field intensity at particular locations in Section 73.686(d) are a modest variant of the standard engineering protocol used worldwide for verifying coverage, verifying transmit antenna radiation patterns, and developing propagation algorithms used in planning for allocation of broadcast station spectrum. With certain minor adjustments, the procedures set forth in Section 73.686(d) will work well for measuring *digital* signal strength.

57. The first necessary adjustment is obvious: when testing for the availability of a digital signal, the minimum field strength values will be different (*e.g.* 41 dBu for UHF) than for analog signals. In addition, as the Commission observes, unlike with analog, there is no visual carrier for digital signals, so measuring the visual carrier is not an option. NOI, ¶ 13.

58. A second necessary adjustment is this: the instrument used to measure DTV signal strength in the field must be different from the ones currently used to measure the narrow-band NTSC video signal. Use of existing analog NTSC field strength meters will *not* be sufficient, since they do not measure the entire DTV signal power, which utilizes almost the entire 6 MHz channel (DTV has an equivalent noise bandwidth of 5.381 MHz). The Commission defines DTV signals by their *integrated average power* in a 6 MHz bandwidth, whether describing transmitter power output (TPO), its effective radiated power (ERP), or its field strength at the input to a receive antenna or the input power to a DTV receiver.

59. A power measurement instrument must therefore be used that can tune to the center of the DTV RF channel and measure this integrated power over 6 MHz. This instrument may take the form of a common swept-tuned spectrum analyzer that has a variety of small IF

bandwidths from which to select (small compared to the 6 MHz DTV signal bandwidth), and can easily integrate (sum up) the total DTV power across 6 MHz (*e.g.*, by use of band power markers). Examples of such instruments are the Agilent E4402B or Rhode & Schwarz FSH-3 spectrum analyzers. However, a low-noise amplifier should be included prior to the power measurement instrument to ensure that the receive system measurement sensitivity (antenna, coaxial cable, and power measurement device) is sufficient to accurately measure the weakest of signals (i.e., 41 dBuV/m). Alternatively, the power measurement device can take the form of a calibrated field strength meter that has one fixed narrow bandwidth, but can be *swept* across the entire 6 MHz band -- integrating the power in each IF sub-band as it sweeps to produce the correct total power. An example of such an instrument is the Z-Technology R507 that is routinely used for measuring DTV field strength in coverage testing. Finally, such a power measurement device could take the form in the future of a calibrated fixed tuned receiver that has an IF bandwidth equal to the 6 MHz DTV channel. But under no circumstances should a power measurement device simply measure the pilot power in a narrow band, and then calculate the total power from this value. This is due to the fact that in the field, multipath can create sharp peaks and valleys in the DTV spectrum that, if one is measuring only a narrow band, could easily cause measurement errors in the ± 10-dB range.

60. In addition, the testing should ***not*** be done with a simple half-wave dipole but with a calibrated directional antenna with characteristics consistent with the planning factors, such as the Channel Master 4228 or the Winegard Square Shooter SS-2000. Based on our practical experience from thousands of field tests, use of an antenna with gain helps greatly in ensuring that the power levels (after line loss) are sufficiently high to permit accurate measurements at all channel ranges. Also, a calibrated directional antenna should be utilized

rather than a simple ½-wave dipole antenna since a ½-wave dipole antenna has very little directivity and no front-to-back ratio protection as would be needed per the FCC allocation planning assumptions. Significant measurement errors could easily occur from multipath signals from the rear as well as from nearby interfering analog and digital stations if a simple ½-wave dipole antenna were used.

61. The height of the receiving antenna above ground level should be as set forth in the existing regulation: 20 feet for one-story residences, and 30 feet for two-story residences. The Commission should not permit testing to be done of *indoor* antennas, a step that would be inconsistent with the premise of the DTV transition that households will make the same efforts to receive digital signals that they have historically made to receive analog signals. In addition, indoor testing would be impossible to standardize.

<u>Use of Signal Strength as a Proxy for Picture Reception</u>

62. In ¶ 14 of the Notice of Inquiry, the Commission inquires about whether *objective* signal strength, or instead some other metric, should be used to determine whether a household can receive an over-the-air digital signal. As we discuss here, an *objective* signal strength test is an excellent proxy for availability of digital service and will avoid the serious technical and practical problems with implementing a *subjective* test – whether for analog or digital service.

63. With both analog and digital television, the availability of a signal level above the minimums set forth in the rules is a very good proxy for ability to receive a picture. (With digital, subject to certain exceptions, if one gets a picture at all, it is a high-quality picture.)

64. There exist abundant empirical data showing that the ability to receive a digital signal above the thresholds specified in the Commission's rules (*e.g.*, 41 dBu for UHF) is in fact

a strong indicator of ability to receive a high-quality digital picture. Between 1994 and 2001, engineers conducted thousands of field measurements – in 15 separate measurement programs for different digital transmitters, across 12 different cities – to evaluate both (i) whether a signal above the minimum field intensity was present at a particular location and (ii) if so, whether the system achieved successful *reception* at that location. For present purposes, the key statistic from these tests is the "System Performance Index": the percentage of sites with signal levels above the FCC-defined minimum field strength value that had successful DTV reception. This statistic is relevant for the Commission's current purposes, namely determining whether signal strength is a good proxy for the ability to receive a picture. (Again, with digital, it will generally be true that if one can receive a picture at all, it will be a high-quality picture.)

65. Before discussing the results of these studies, an important qualification is in order: the receivers used for *all* of these tests were, by present standards, relatively primitive. As discussed in more detail below, this fact is significant, because newer-generation receivers are far better than the receivers used in these historic tests at handling difficult reception environments, and in particular at resolving multipath problems. Thus, if the same tests were done today, one can be confident that the System Performance Indices for these locations would be higher still.

66. The DTV receiver used in 11 of the 15 field testing programs was the original Grand Alliance prototype ("blue rack") receiver. This hardware is now known to have significantly worse equalizer performance than either fourth generation receivers (widely available today) or the fifth generation receivers discussed in detail below. As documented in recent years (**Ref 13, 14**), the Grand Alliance receiver had an equalizer range of only –3 to +22 usecs compared to the ±50 usec of the fifth generation receiver. It also did not apply data-

directed equalization to the decision-feedback section that handled multipath delays from +3 to +22 usec, and thereby had very poor dynamic performance in this echo delay range. Also, the Grand Alliance receiver did not handle multipath with amplitudes greater than 3 dB (70%), whereas recent 5th generation chip sets easily handle 90 – 95% and even handle 0 dB (100 %) echoes within a certain delay range. Finally, the AGC speed of the Grand Alliance receiver was less than 10 Hz while most modern day DTV receivers utilize speeds greater than 100 or 200 Hz. The four testing programs that did *not* use the original Grand Alliance receiver utilized either a second generation VSB chip (two tests) or a third generation VSB chip (two tests). Not one of these 15 field tests employed a fourth generation (or later) VSB chip in the reference DTV receiver.

67. **Table 7** summarizes the System Performance Index results from the 15 digital field test programs conducted between 1994 and 2001 with these relatively low-quality receivers:

Station Call Letters	City of Testing	CH #	System Performance Index (%)
ACATS	Charlotte 1994	53	95.8
ACATS	Charlotte 1994	6	82.2
WRAL	Raleigh 1997	32	95.4
WGN	Chicago 1998	20	93.7
KICU	San Jose 1998	52	98.7
WCBS	N.Y. City 1998 & 1999	56	88.2
WFAA	Dallas 1999	9	96.1
WMVS	Milwaukee 2001	8	98.2
WHD	Washington DC 1997 & 1998	30	81.9
WETA	Washington DC 1997 & 1998	34	83.4
KOMO	Seattle 1998	38	78.1
KING	Seattle 1998	48	76.8
WKRC	Cincinnati 1999	31	91.9
KYW	Philadelphia 1999 & 2000	26	94.0
KMOV	St. Louis 2001	56	93.4
Average	------	------	**90.0**

Table 7 Field Test results from 1994 through 2001

68. As these results show, with low-quality, early-generation receivers, the average System Performance Index across these 15 testing programs was 90%. To the extent that the tests showed that a signal above the minimum was present but that reception was not

successfully achieved, the culprits are in most cases multipath or interference problems. But as discussed below, newer generation receivers do far better at handling difficult reception environments, including "concrete canyon" multipath problems (such as in Rosslyn, Virginia). With these higher-quality receivers – which the DBS companies can readily incorporate into their own set-top boxes – the System Performance Index will likely be even higher than the 90% figure from the tests several years ago.

69. The alternative to an objective signal strength test would presumably be some form of picture quality test. During the testing phase of the digital rollout, engineers have typically checked both signal strength and picture quality. But despite the well-known "cliff effect" for digital pictures, evaluating whether digital reception has been achieved by watching the picture on a screen nevertheless requires subjective judgments.

70. Ordinarily, the digital cliff effect causes a DTV set to either display a moving picture or a blank screen (or blue screen, in some cases). But there are times when the DTV signal is near threshold and occasional excursions below threshold occur, causing occasional (MPEG) "blockiness" or an occasional brief freeze frame. Determining whether this picture is acceptable or not is a subjective assessment, just as with analog television. What makes things even more difficult is the fact that DTV receivers often employ some form of error concealment in their decoder circuitry (such as repeating the macro block information from the last frame) that tends to hide the errors on static portions of the picture. Therefore, the exact MPEG packets lost may or may not show up on the screen for the test viewer, depending on the video content. Evaluating whether there is an unacceptable level of flaws in the picture therefore requires complex and subtle judgments.

71. Expecting difficult subjective judgments to be made fairly and accurately in the hotbed environment of a test at a subscriber's home is not realistic. Because the availability of a signal above the Commission minimums is such a good proxy for successful reception, the Commission should ensure a manageable testing process by continuing to rely on objective signal strength as the key test.

72. Another alternative – which we mention for the sake of completeness but do not recommend -- would be to rely on an additional objective test for assessing whether successful reception can be achieved. This method was developed during the ACATS lab testing at Advanced Television Test Center in Alexandria VA in 1995 (Ref 13). To determine if Bit Error Rate (BER) measurements could be used at ATTC to accurately determine threshold of visibility (i.e., visible errors, or TOV) rather than using expert observers (of the video), a subset of 11 different tests were performed using both methods of TOV determination. The results of comparing the subjective video and the objective BER indicated that TOV could be determined within ± 0.5 dB. Bit Error Rate (BER) was selected at ATTC rather than the preferred MPEG Packet Error Rate (PER) measurement because no third-party test equipment was available at the time of the ACATS testing.

73. Therefore, a professional VSB demodulator, with fifth generation decoder performance and packet error rate (PER) readout capability can accurately, quickly, and objectively determine TOV for a digital signal without having the DTV station go off the air, provided that an appropriate antenna and other test equipment are used. However, because of the added complexity of ensuring that such a test is done correctly, we do not recommend it.

Evaluating the Accuracy of the Longley-Rice Model in Predicting Whether <u>Signal Strength at Particular Locations is Above or Below the DTV Minimums</u>

74. The Commission states in its Notice of Inquiry: "We believe that the modified Longley-Rice is an accurate, practical, and readily available model for determining signal intensity at individual locations when used with analog signals." Based on our experience, we endorse that conclusion; Longley-Rice has an excellent track record of predicting whether particular locations will, or will not, receive a signal above the analog threshold (e.g., 47 dBu for low-VHF).

75. We present here extensive data showing that the same conclusion applies to Longley-Rice's performance in predicting digital signal strength. As discussed above, engineers performed thousands of digital signal intensity tests between 1994 and 2001 in 15 different testing programs in 12 different cities. We have analyzed 2,169 of these locations (those for which data could be analyzed in this time frame) using the same method described by the Commission in its 2000 ILLR Order, namely comparing the Longley-Rice predictions for these locations (*i.e.*, whether the household is predicted to be above or below the signal strength minimum) with the actual measured signal strength for the same locations (*i.e.*, whether the household was measured to be above or below the signal strength minimum).

76. The results show – with a large sample size – that the Longley-Rice model does well when judged against actual measurements. All told, the model correctly predicted that the signal would be above (or below) the noise-limited threshold at 2,047 locations out of a total of 2,169 (94.4%).

Evaluating Whether Addition of a Clutter Factor to the Digital
<u>Longley-Rice Model Would Make the Model More Accurate</u>

77. The Commission asks (NOI, ¶ 7) whether it needs to add an extra "clutter" factor to the standard digital Longley-Rice model. (The Longley-Rice model is in part based on actual field measurements (from land mobile measurements in Ohio and Colorado plus the original TASO data from the 1950s), and, to that extent, already takes clutter into account, without the need for a special clutter factor.) As the Commission recognized in 2000, whether a clutter factor will make the standard Longley-Rice model more accurate is an empirical issue. For example, in 2000 the Commission found that adding a clutter factor for analog UHF channels would make the model more accurate, but that adding a clutter factor for analog VHF channels would make it less accurate. *In Re Establishment of an Improved Model for Predicting the Broadcast Television Field Strength Received at Individual Locations*, ET Docket No. 00-11 (May 26, 2000). The Commission's finding was based on a review of the accuracy of the model – and the extent to which it "underpredicts" or "overpredicts" actual test results. No model of RF signal propagation will predict correctly 100% of the time, *see* NOI ¶ 15 n.14 ("the absolute intensity of broadcast signals at particular locations and at particular times cannot be precisely determined through predictive means, regardless of the predictive method used."). The goal is therefore to have a model that achieves high accuracy and whose errors are roughly balanced between underpredictions and overpredictions.

78. For the small percentage of cases (5.6%) in which the Longley-Rice model did not accurately predict whether the location would be above or below the noise-limited threshold dBu level, we have performed a similar "overprediction / underprediction" analysis of the Longley-Rice model. The results show that the model is already in balance without the addition of an extra clutter factor. The incorrect predictions (122 locations out of 2,169) were split

between 49 locations where the measured value was greater than the predicted and 73 locations where the measured value was less than the predicted value. Breaking the analysis down by TV-bands (low-VHF, high-VHF, and UHF) yields the following **Table 8.**

Band	Total Number of Sites Measured	Correct Predictions	Over Predictions	Underpredictions
Low VHF	93	96.8 %	0.0 %	1.1 %
High VHF	464	92.0 %	4.1 %	5.8 %
UHF	1,612	94.9 %	3.4 %	1.4 %
All Bands	2,169	94.6 %	3.4 %	2.3 %

Table 8 Comparison of Measured vs. Predicted Field Strength

(Note: Based upon 41dBu Threshold for UHF)

79. [Intentionally omitted.]

Challenges In Implementing a Digital Longley-Rice Model in
<u>the Near Term for Purposes of the Satellite Home Viewer Act</u>

80. In a world in which matters have "settled down," Longley-Rice is an excellent predictive model, as discussed above. In the near term, however, the world of digital broadcasting has not settled down, but is in a state of rapid flux.

81. The Commission may wish to consider two eras in which the Longley-Rice model might be used for purposes of determining whether households can receive digital signals over the air: the *long term*, after the transition from analog to digital is complete, and the *short term*, before that date.

82. In the long term, when the transition from analog to digital television broadcasting is complete, there *may* be an unavoidable need for a digital Longley-Rice model to predict which households are "unserved" over the air by a station affiliated with the relevant

network. Whether there will be such a need depends, of course, on whether the DBS companies have then completed their rollout of digital local-into-local service in all 210 DMA. (Under SHVERA, we understand that once digital local-to-local is available in a particular market, the issue of over-the-air availability of digital signals becomes irrelevant. 47 U.S.C. 339(a)(2) ("Replacement of Distant Signals with Local Signals").

83. We understand that DIRECTV has already announced plans to deliver more than 1,500 local stations in high-definition by 2007, beginning with stations in 24 large markets (covering some 45% of U.S. television households) during 2005. Given competition in the industry, EchoStar may well follow suit.

84. Hence, there is an open question whether, at the end of the transition, there will be a need for a "digital ILLR" model to predict signal strength in any local markets. In the meantime, the FCC must report to Congress its views about whether to give legal effect *in the near term* to Longley-Rice predictions about whether particular households are, or are not, able to receive digital signals of network affiliates over the air.

85. In the *short term*, there are serious practical problems with applying the Longley-Rice model, including the following:

a. **Congress has postponed the date on which many broadcast stations can be "tested" – or, presumably, have their digital service predicted by Longley-Rice**. To avoid punishing a station for failing to deliver a digital signal when it cannot reasonably be expected to do so, Congress created a multistage timetable about when particular stations are eligible to be tested. 39 U.S.C. § 339(a)(2)(d)(vii) ("Trigger Dates for Testing"). The schedule includes the following:

April 30, 2006 trigger date for testing:

- stations in the top 100 markets that (i) have chosen a tentative digital television service channel designation that is the same as the station's current digital television service channel, and (ii) that have not been granted a testing waiver pursuant to 39 U.S.C. § 339(a)(2)(d)(vii); and
- stations in the top 100 markets that have been found by the Commission to have lost interference protection.

July 15, 2007 trigger date for testing:

- stations in the top 100 markets that (i) have chosen a tentative digital television service channel designation that is different from the station's current digital television service channel, and (ii) that have not been granted a testing waiver pursuant to 39 U.S.C. § 339(a)(2)(d)(vii); and
- stations below the top 100 markets that have not been granted a testing waiver pursuant to 39 U.S.C. § 339(a)(2)(d)(vii).

Unknown future trigger dates for testing:

- ***translator stations*** will be subject to testing "one year after the date on which the Commission completes all actions necessary for the allocation and assignment of digital television licenses to television translator stations," except to the extent that the translator station has been granted a testing waiver pursuant to 39 U.S.C. § 339(a)(2)(d)(ix);
- ***full-power stations that have obtained testing waivers*** will continue to be exempt from testing for as long as the Commission continues to approve six-month extensions of an existing waiver.

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In the context of a *predictive model,* this is a high level of complexity to manage.

b. <u>Many stations that are *exempt* from having their digital signals evaluated would require analog predictions as an alternative</u>. We understand that under the Satellite Home Viewer Act and its successors, a household is unserved if it cannot receive a signal from *any* facility transmitting a station affiliated with the relevant network (say, ABC). Thus, if a household can receive a signal from a *translator* that retransmits the signal of an ABC station, the household is not eligible to receive a distant ABC station. Similarly, if the household can receive a signal from a nearby ABC station, it is not eligible to receive a distant ABC station, whether or not the station happens to be in the same local market as the subscriber. Thus, if a household in a top-100 market can receive a digital signal from a CBS station over the air from a neighboring below-top-100 market, we understand that it is not eligible to receive a distant signal, whether or not it can receive the signal of the CBS station in the larger market.

As indicated, Congress has ruled that certain stations may not have their digital signal "tested" until some time in the future. This principle would presumably apply to any predictive model as well.

What does this "no testing / no prediction" rule mean as a practical matter? Consider the following example: suppose a household near the Shenandoah Mountains in Virginia is now predicted to (and can) receive an analog signal of a Washington, D.C. network affiliate from a translator station. Congress has decreed that the digital signal of this translator station cannot be "tested" until some future date – which is no surprise, since the station does not even have a digital channel assignment yet. How, then, should this translator station – which is currently transmitting only in analog – be treated for purposes of tests, and for purposes of predictions?

If a station is not yet eligible to have its digital coverage evaluated, one must give the station "credit" for its *analog* service area. Thus, when a *test* is performed at such a household, the tester must look for the digital signal of any (for example) ABC affiliate that might be available over the air, and *also* for the analog signal of any ABC affiliate that is not yet subject to digital testing. Since there is no digital signal to test, this appears to be the only logical method of giving stations "credit" for their coverage when they have been excused (for now) from digital testing. This result is also reasonable in that the eventual goal of the digital rollout will be to replicate the stations' current analog coverage areas.

The need for a constantly evolving "analog / digital hybrid" would therefore add still greater complexity to a nationwide predictive model about digital signals.

c. **Station channel assignments are still in flux**. The Commission and the broadcast industry are still in the midst of the "repacking" process and of other regulatory decisions that must be made before all stations settle on their final digital channel. Under the timetable announced last week in MM Docket No. 03-15, not until August 2006 will the Commission issue a Notice of Proposed Rulemaking proposing a new DTV Table of Allotments, which will then be subject to comment by the public and potentially to significant revision by the Commission thereafter. The continuing movement by stations to different channels will add a further challenge to both the testing process and to application of the Longley-Rice model.

86-91. [Intentionally omitted.]

92. This does not mean that the Longley-Rice model would have no role in determining subscriber eligibility for distant signals in the short run: we understand that the Act already provides that households predicted by the ILLR model to be unserved by over-the-air *analog* stations are eligible to receive distant digital stations. Thus, the convenience to both

consumers and satellite companies of the ability to rely on a predictive computer model will continue to be available.

Major Improvements in Fifth-Generation DTV Receiver Boxes

93. As discussed above, even with early and unrefined digital receivers, the results of thousands of real-world tests show that if a digital signal above the noise-limited threshold is available, it is possible to achieve successful (and high-quality) DTV reception 90% of the time. That figure will increase substantially in the near future: the results of extensive lab and field tests show that fifth-generation DTV receivers achieve far better performance in difficult reception environments (such as multipath) that contributed to the small number of reception failures in past tests. Since DBS customers regularly replace their set-top boxes for a variety of reasons anyway, and since the DBS firms are currently in the process of switching their customers to new set-top boxes for another reason (to use MPEG-4 compression),[1] it will be a simple matter for most DBS customers to be able to take advantage of this advanced technology. Indeed, while the DBS companies collectively have tens of millions of subscribers, the number of DBS subscribers who have *high-definition-compatible* receivers is vastly smaller. Only DirecTV and EchoStar know these numbers for certain, but our understanding based on industry information is that they are very low.

94. Since the adoption of the DTV standard and the first DTV receivers appeared on the market in late 1998 and early 1999, there has been a new "generation" of VSB receiver approximately every two years. Using the information learned from DTV field tests and RF field

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[1] *See Sharper Vision For Local Ambitions: DirecTV Places a Big Bet on High-Definition Local Channels*, Multichannel News (May 23, 2005) ("Even DirecTV subscribers who already watch national HD programming will need new dishes and receivers using MPEG-4 (Moving Picture Expert Group) compression technology to receive local HD signals."); *EchoStar Wants to 'See the Playing Field' Before Making HDTV and Broadband Bets*, Satellite Week (May 9, 2005) (discussing expanded rollout of MPEG-4 in 2006 including production of new set-top boxes)

data captures, novel equalization algorithms and advanced hardware architectures have been developed to handle severe multipath conditions. Using a variety of new simulation tools, much was learned about real-world propagation environments, which led to the departure from traditional implementation hardware. Along with improved equalization capability, synchronization (carrier, clock, & data packet) and tuner overload performance have been improved as well.

95. To appreciate where the DTV receiver has come from, a bit of history is helpful. The performance improvement of the various generations of DTV receivers has been significant **(Ref 15)**, as can be seen from **Figure 2.** The first- and second-generation receivers had very short pre-echo and post-echo equalizer ranges, limiting their performance to short ghosts. Note that any multipath that is *longer* than the equalizer hardware (equivalent to a tapped delay line) can only withstand an 18% ghost (i.e., D/U = 15 dB) under *strong* signal conditions before the data eyes are closed and the forward error correction (FEC) overrun. In weak signal conditions (i.e., low SNR), the situation is even worse in that a ghost *smaller* than 18% along in concert with the receiver's white noise can close the data eyes and cause errors. In addition to this liability, the early receivers did not use the predictive slice methodology for creating the sliced data-directed reference signal for the equalizer's ghost-canceling algorithm, thus weakening its performance.

96. The third generation recognized the need to handle longer ghosts, and therefore increased the equalizer *range* of post-echoes significantly (≈ 45 μsec) and increased the Doppler tracking speed as well as the robustness. However, the pre-echo cancellation range was not increased.

97. Each generation of 8-VSB receiver has had major improvements, but the fourth generation offered the most significant improvement up to that time. In that generation, designers recognized that pre-echoes were just as important as post-echoes, and addressed the issue in part. (Pre-echoes occur when the main signal (direct path) is attenuated by terrain or some object, and a delayed version of the signal is stronger than the main signal.)

98. The most remarkable improvement, however, has come with the fifth generation receivers. The primary goal of the fifth generation receiver was improved indoor DTV reception with simpler antennas, minimal antenna positioning, and stable reception in the presence of moving people within the room. But as discussed below, the success of the fifth generation receivers in combating multipath also makes for superior results with outdoor antennas in areas with such reception challenges.

99. With fifth-generation receivers, the new equalizer architecture and algorithm enhance convergence under combinations of complex multipath and noise. Equalizer convergence to the correct final solution in a speedy manner has been improved by *starting* the process with an accurate estimate of the severely distorted channel response rather than starting from a fixed condition. Equalizer range has been significantly increased (*e.g.*, 50 μsecs) in *both* pre-echo and post-echo directions. LMS algorithms track moving (Doppler) multipath, aided by new zero-delay trellis decoders that provide fast, accurate error estimates for the equalizer algorithm from the 8-level data.

100. In both *lab* testing and *field* testing, the new fifth-generation VSB receiver has outperformed previous generations of DTV receivers.

101. In lab tests, the receiver has been confronted with severe multipath "ensembles" – recordings of RF transmissions in severe multipath environments. **Table 9** (from **Ref 15**) describes the various test ensembles, and the receiver performance of each generation.

Multipath Description	2G	3G	4G	5G
ATTC D	**Pass**	**Pass**	**Pass**	**Pass**
Brazil A	**Pass**	**Pass**	**Pass**	**Pass**
Brazil B	*Fail*	*Fail*	*Fail*	**Pass**
Brazil C	*Fail*	*Fail*	*Fail*	**Pass**
Brazil D	*Fail*	*Fail*	*Fail*	**Pass**
Brazil E	*Fail*	*Fail*	*Fail*	**Pass**
CRC-3	*Fail*	*Fail*	*Fail*	**Pass**
CRC-4	*Fail*	*Fail*	*Fail*	**Pass**

Table 9 VSB Generation comparison of multipath performance (multipath complexity increased from top to bottom)

102. When a fourth generation and fifth generation receiver were compared to each other in the lab using the 50 RF field data captures (from Washington, D.C. and New York City) recommended in the A/74 ATSC Receiver Performance Guidelines (**Ref 16**), the number of "reception failures" was cut by a factor of five.

103. The results of *field* tests are similarly encouraging. As reported in a paper published by the IEEE, when tested in the field in Washington, D.C. (MSTV), Ottawa Canada (Canadian Research Center), and Baltimore, MD (Sinclair Broadcast Group), similar dramatic improvements were documented between older generations and the new fifth generation VSB receiver. In Washington and Baltimore, engineers visited not *typical* receive sites but *known, difficult* receive sites – and nevertheless found that the fifth generation receiver was able to achieve reception where prior generations had failed.

Additional Information About Lab Testing Of Fifth Generation Receivers

104. Two early versions of fifth generation VSB decoder prototype chips were *independently* tested at Communication Research Centre (CRC) in Canada. These test results indicated a significant improvement in multipath performance.

105. In the Linx test **(Ref 17)**, Linx Electronics Inc. (now owned by Micronas) sent an early prototype rack (FPGA circuit board encased in a 19" rack) to CRC to be tested in March 2002. The new prototype was a state-of-the-art receiver "designed to operate under severe channel degradation, including the possible nulling of the VSB pilot." The hardware contained a single-conversion consumer-grade tuner and a 10-bit A/D converter, along with an equalizer with "a unique configuration that enables proper equalization of strong ghosts while minimizing equalizer noise enhancement."

106. In the Zenith/LGE test **(Ref 18)**, an early prototype rack was tested in September 2003. Likewise, it had significantly new architecture design that provided significant improvement in multipath cancellation. Similar tests were performed on the LGE unit as was done on the Linx unit. (The data is summarized below.)

107. While many tests were performed at the CRC labs, the following is a brief discussion of some of the pertinent tests that illustrate the primary improvements to the DTV equalizer and tuner performance.

108. The first comparison test is the white noise threshold test, which is performed with no impairments or signal distortion to the DTV signal other than added noise. Both prototype 5G units have the characteristically low white noise threshold of just over 15 dB, C/N that contributes to the needed sensitivity of DTV receivers The results are shown in **Table 10.**